CONFIDENTIAL

Columbia University
in the City of New York

GEOPHYSICAL FIELD STATION
ST. DAVID'S, BERMUDA

MAIL ADDRESS:
NAVY SOFAR STATION
APO NO. 856, NEW YORK, N.Y.

CONFIDENTIAL

CONFIDENTIAL

Ser.#01-64

TECHNICAL REPORT

SEPARATION OF OVERLAPPING SIGNALS FOR TIMING PURPOSES

by
Miles Mayall and G. R. Hamilton
Columbia University Geophysical Field Station
St. David's, Bermuda

January 1964

Acknowledgments

This research work was supported by the Field Projects Branch (418) of the Office of Naval Research under Contract Nonr266(65) with Columbia University

CONFIDENTIAL

CONFIDENTIAL

ABSTRACT

The hydroacoustic signals from multiple SOFAR charges carried by the Polaris A3 occasionally overlap each other making it difficult for the Missile Impact Location System (MILS) to compute positions. A method of separating such signals using narrow band filters set at the bubble pulse frequency null of one of the charges to enhance the other is described.

Security Classification

This report is classified CONFIDENTIAL for two reasons:-

1) Reference is made to the multiple SOFAR charges in the Polaris A3 missile.

2) AMR test numbers and dates are given for two Polaris A3 submarine launched missiles.

CONFIDENTIAL

CONFIDENTIAL

SEPARATION OF OVERLAPPING SOFAR SIGNALS FOR TIMING PURPOSES

INTRODUCTION

For the Missile Impact Location System (MILS) utilization where multiple SOFAR charges may detonate in close time or space proximity an identification and timing problem occasionally arises with one large SOFAR signal obscuring another smaller one. In the Atlantic at Fernando de Noronha and Ascension this overlap problem will occur more often than at other MILS stations due to the continuous high amplitude of the received SOFAR signals. At other stations, particularly the suspended BOA hydrophones, the final build-up to the SOFAR cutoff is sudden (a second or two) and large (10-15 db) so that the problem arises less often.

There have been several examples of this SOFAR signal overlap problem in recent Polaris A3X tests on the Atlantic Missile Range. In AMR Test #1255 of Feb '63 at Fernando and Ascension the 4 lb SOFAR signal obscured the 1 lb SOFAR signal. In AMR Test #3305 of 14 Aug '63 at Bermuda the 2 lb obscured the 1/2 lb SOFAR signal. In AMR Test #5343 of 26 Oct '63 the 4 lb obscured the 1 lb at Noronha and Ascension, and the 4 lb obscured the 2 lb at Bermuda and Eleuthera. In AMR Test #5347 of 11 Nov '63 the 4 lb obscured the 2 lb at Canary's and Ascension. This report describes a method of enhancing the small SOFAR signal so that its cutoff may be precisely timed.

CONFIDENTIAL

SOFAR CHARGE HYDROACOUSTIC FREQUENCY SPECTRUM

In an underwater explosion, after the emission of the shock wave, an unstable bubble is formed as the surrounding water flows radially outward due to inertial impact of the passing sho ck wave. This bubble radius far overshoots the equilibrium bubble radius at which the internal gas pressure due to the chemical explosion products equals the hydrostatic pressure. After the spherical bubble expansion has been brought to a stop by the hydrostatic pressure of the surrounding water, the bubble violently collapses followed by another expansion, this occurring sometimes as many as 6 or 8 times. At the time of the first collapse an acoustic pressure wave is emitted, known as the bubble pulse. A successively smaller pulse is emitted at each succeeding minimum (see Figure 1), but only the first bubble pulse has sufficient energy to add to the acoustic signal of the shock wave to form the SOFAR signal. Although the peak pressure of the first bubble pulse is far less than that of the shock wave, the low frequency components are of about equal size.

The time interval between shock wave and the emission of the bubble pulse is known as the bubble pulse interval. Its length depends on the weight of the explosive charge and the detonation depth of the explosion. The frequency spectrum of the radiated hydroacoustic signal has a series of harmonic lines at a frequency spacing given by the reciprocal of this time interval. This frequency is called the bubble pulse frequency and its harmonics are the most obvious thing in the SOFAR signals' hydroacoustic frequency spectrum. Figure 2 shows the hydroacoustic spectrum of a 4 lb HBX SOFAR charge detonated at 3400 feet. Here

the high frequency components of the signal have been boosted by 12 db per octave to the frequency where the SOFAR signal level is not much above the background electronic noise at the upper frequencies of the figure. The bubble pulse interval is 1/115 second for this charge and the eadiated hydroacoustic signal has a series of broad harmonic frequency lines spaced 115 cps apart. These are most easily seen by noting the frequency minimums at 172, 287 and 402 cps. These correspond to 3/2, 5/2 and 7/2 of the fundamental bubble pulse frequency. At these wave lengths the initial shock wave will be 180° out of phase with its following concentric bubble pulse wave resulting in acoustic interference or cancellation of these frequencies in the SOFAR signals' hydroacoustic spectrum.

The upper frequency limit of the SOFAR signal frequency spectrum is limited by the attenuation in the sea water over long transmission paths and by the poor high frequency response of the MILS hydrophones with their long submarine cables. At short range, harmonics as high as the fortieth can be seen in the frequency analysis of such a SOFAR signal.

METHOD OF SEPARATING SOFAR SIGNALS UTILIZING BPF

As mentioned above, the null lines in the SOFAR signals' frequency spectrum depend on the charge size and detonation depth. Typically, a 4 lb HBX and a 1 lb HBX have their lowest null frequencies at 170 cps and 255 cps respectively. The method of enhancing the small SOFAR signal on the Sanborn recorder is to record the combined signals through a narrow band filter set at one of the bubble pulse null frequencies of the larger

signal. This rejection of the large signal emphasizes the small signal. Normally, the frequen cy components of 1 lb SOFAR signal level would be about 12 db below that of the 4 lb signal (approximately 6 db for each halving of the explosive charge weight).

AMR TEST #1255 - Fernando de Noronha

The following procedure was used to separate the overlapping signals for AMR Test #1255 on Fernando de Noronha No. 1 hydrophone shown as the bottom Sanborn trace of Figure 5. The tape recorded signal was first frequency analyzed on a Kay Electric Co. Vibralyzer to determine the bubble pulse null of the larger signal. In the top vibragram of Figure 3 a frequency null at 180 cps can just be seen in the last half of the signal as expected for a 4 lb HBX charge at about 3400 feet. This 4 lb charge bubble pulse null is more apparent in the middle vibragram where the high frequencies were boosted relative to the lower frequencies by filtering the signals through a 200-225 cycle/second bandpass filter (lower filter curve of Figure 7) before it was vibralyzed. Any method of boosting the high frequencies without overloading the lows below the bubble pulse null would be satisfactory. In this middle vibragram of Figure 3 it is now apparent that a shot with a higher bubble pulse frequency null precedes the 4 lb signal. The original tape recorded signal was then played back to a Sanborn graphic oscillograph through one or two sections of 180 cps bandpass filters in a setup as diagramed in Figure 4. The bandpass characteristics of the filters, having a 30 db or a 60 db per

octave cutoff, are shown in Figure 7.

The effect of such a bandpass filter on the Sanborn recordings of a SOFAR signal is shown in Figure 5. In the lower unfiltered trace the small SOFAR signal is not apparent. However, with one and then two Allison filters, the presence of the small SOFAR signal becomes progressively more apparent. It is now possible to precisely time the 1 lb SOFAR signal's cutoff with assurance.

AMR TEST #3305 - Bermuda

The original Sanborn recording of the Bermuda suspended hydrophone for the large SOFAR charge is shown as the lower record of Figure 6. A vibragram of this signal is at the bottom of Figure 3 and has just an indication of a second signal 1.2 seconds ahead of the large signal cutoff. Following the technique discussed above for Test #1255, a filter was set at the 215 cps null frequency of the larger charge and the tape recorded signal played through one and two stage filters to a Sanborn oscillograph. The upper traces of Figure 6 with their easily timed cutoff for the small SOFAR signal resulted.

CONCLUSION

A method of separating overlapping hydroacoustic explosive signals of different bubble pulse frequencies has been described.

The method was developed to make it possible to precisely time overlapping SOFAR signals originating with multiple SOFAR charges carried by a single missile. Typically, the Polaris A3 missile has individual SOFAR charges of different explosive weights that the MILS identifies by the variation in the amplitude of the received SOFAR signals. This is an excellent method of identifying individual SOFAR signals being both simple and inexpensive. The technique described herein eliminates the principal problem, that of occasional overlapping signals that was inherent in this peak pressure identification method.

Distribution:

ONR 418	(2)
" 466	(1)
SP 25	(2)
MTDRD-4	(2)
PMR Pt.Mugu	(1)
LGO	(1)
CUGFS Bda	(2)
ONR SpecRep, Hudson Labs	(2)
CO PMR Hawaiian Area	(1)

(CO PMR Hawaiian Area Facility,
Navy No. 990,
ATT. L. R. Fairbanks,
San Francisco, Calif.)

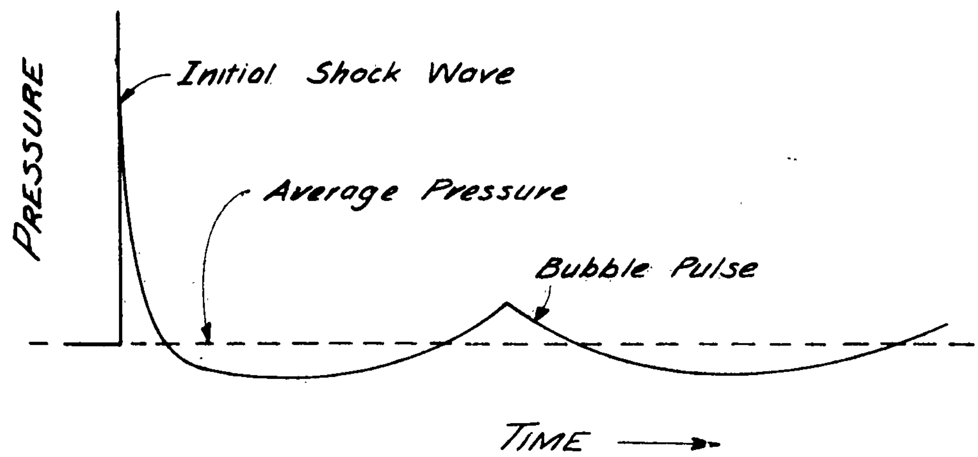


Figure 1

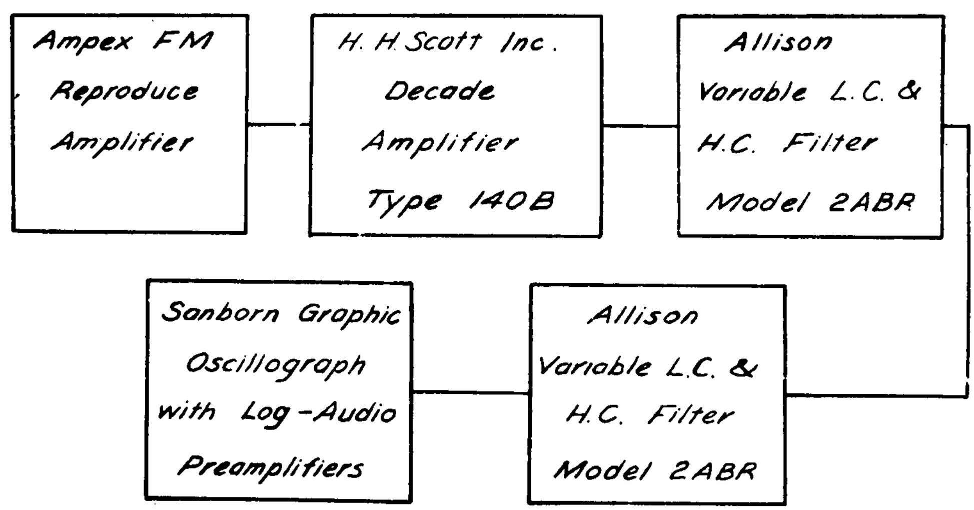


Figure 4

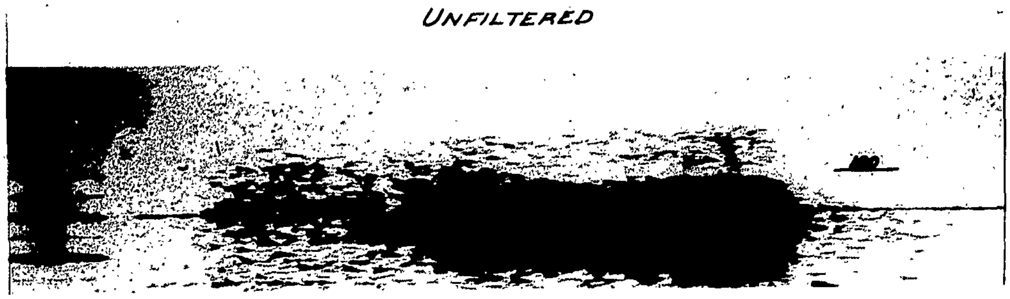
HYDROACOUSTIC FREQUENCY SPECTRUM
OF A SOFAR SIGNAL

4 b HBX Detonated at 3400 ft
at a Range of 900 nm

Figure 2

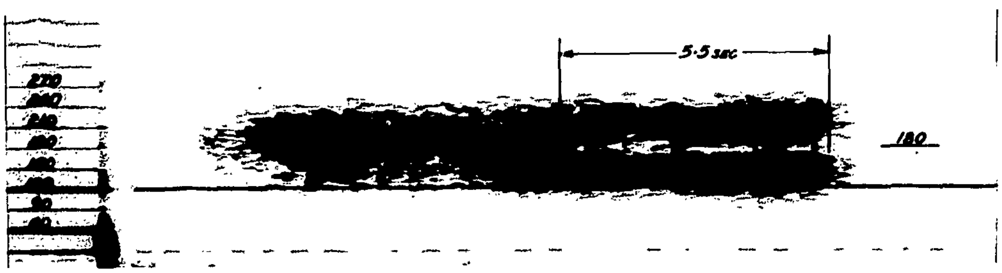
FERNANDO PHONE #1

UNFILTERED



FERNANDO PHONE #1

FILTERED 200 - 225 BANDPASS



LOWER SUSPENDED BERMUDA

12 db/octave HIGH FREQUENCY BOOST

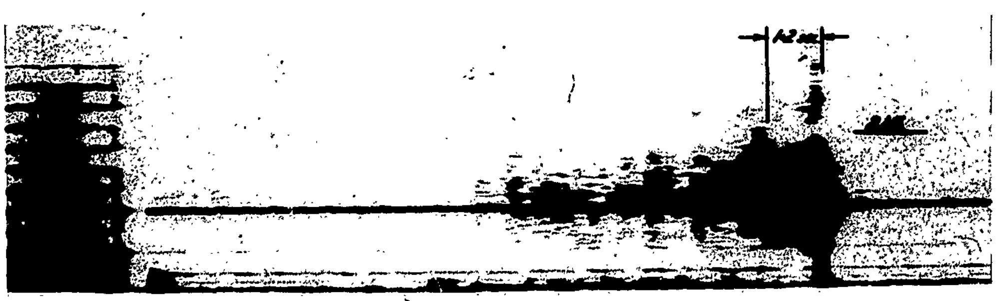


Figure 3

TEST #1255

FERNANDO PHONE #1

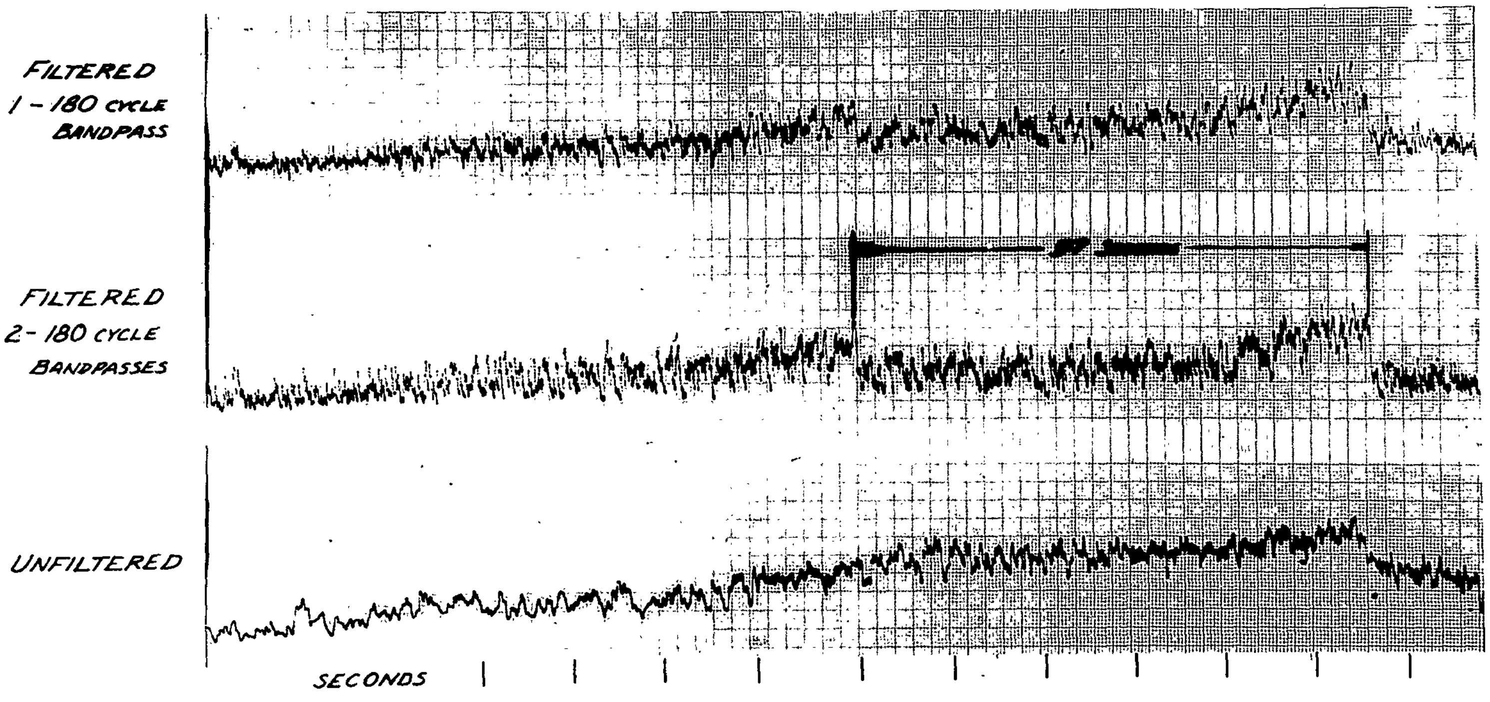


Figure 5

TEST #3305

BERMUDA LOWER SUSPENDED PHONE

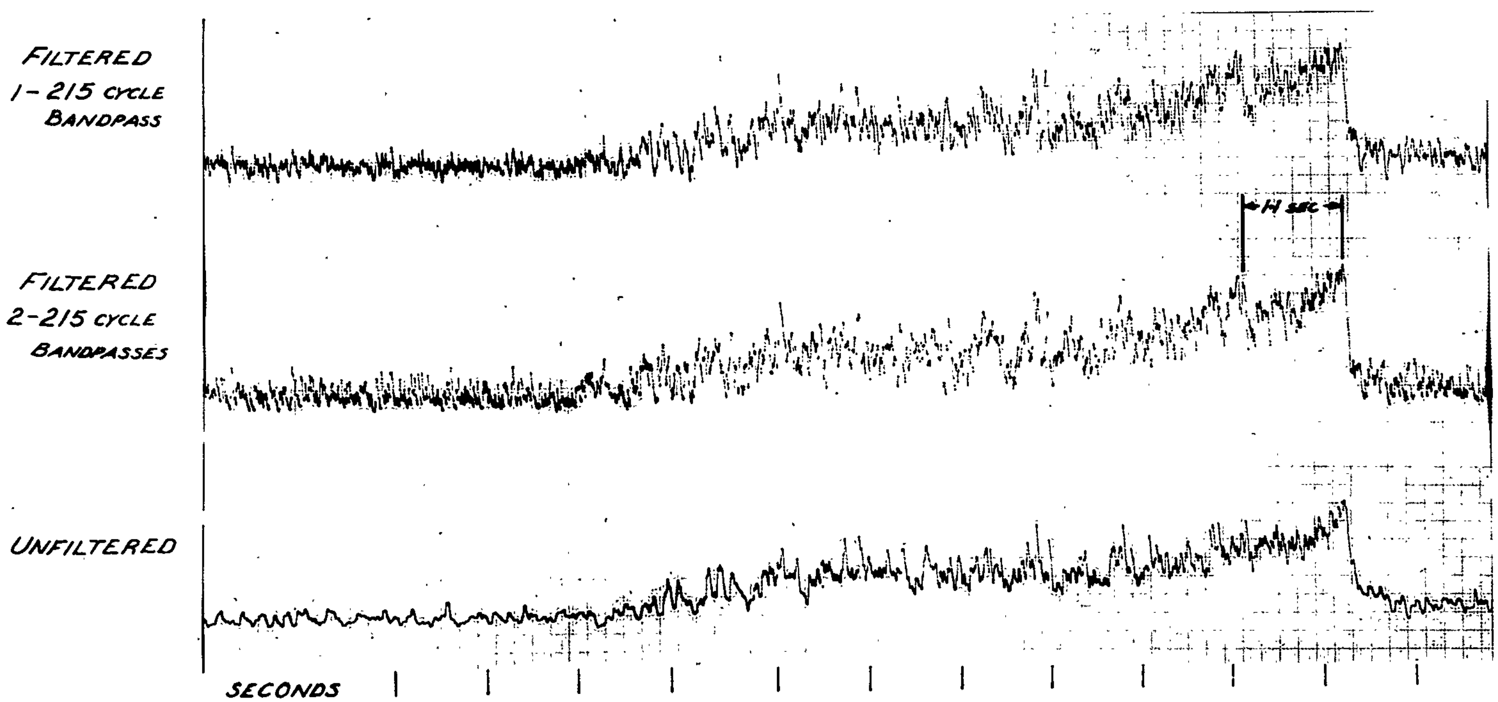
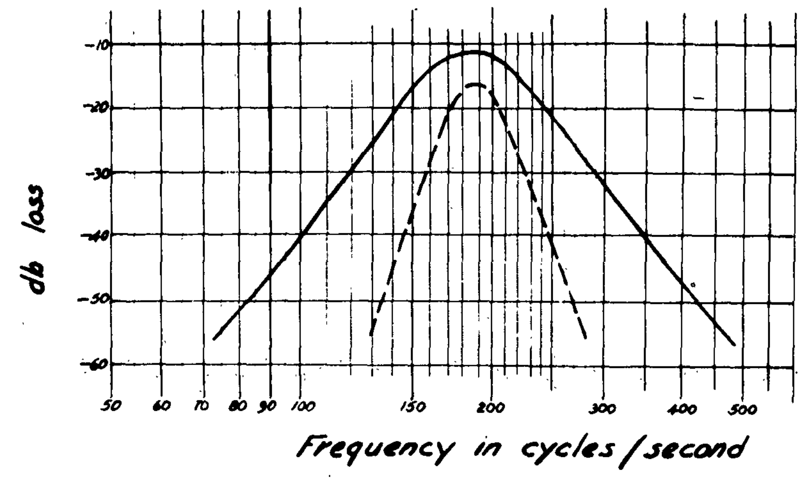
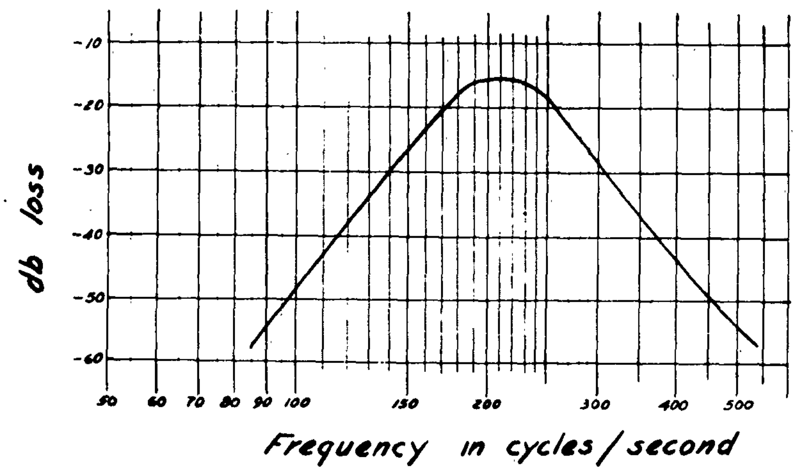


Figure 6



—— One Filter ---- Two Filters in Series

RESPONSE CURVE OF ALLISON VARIABLE L.C. & H.C. FILTERS, MODEL 2ABR, FOR A BANDPASS OF 1/4 OCTAVE CENTERED AT 180 cps



RESPONSE CURVE OF ALLISON FILTER SET AT 200 cps LOW CUTOFF, 225 cps HIGH CUTOFF.

Figure 7.